Climate Economics at the NCCR Climate

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Research Paper
2010/07

NCCR CLIMATE
Swiss Climate Research

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Transfer Design and Incentives for Nationally Appropriate Mitigation Actions in Developing Countries

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October 8, 2010

Abstract

Transfers would play a key role in the implementation of Nationally Appropriate Mitigation Actions (NAMAs) in developing countries. In this paper, we analyze the desirable features of such transfers - i.e., *individually rational*, *budget-balanced*, anti-incentives for *free-riding* and *misrepresentation*. We model NAMAs as a non-cooperative, one shot game. We consider NAMAs under two alternative transfer schemes: a *horizontal equity-based* transfer and an "optimal" transfer scheme that we call *à la Weikard*. Our analysis is further refined by the inclusion of the notion of pivotal countries. We find, firstly, that both transfer schemes may allow the implementation of an *individually rational* and *budget-balanced* NAMAs portfolio; secondly, that the transfer *à la Weikard* is more effective in avoiding free-riding. Thirdly, both transfer schemes fail to avoid *misrepresentation* of costs and benefits from reductions in greenhouse gas emissions. Finally, pivotal countries for NAMAs are the most interested in its implementation even if they are the largest transfer contributors.

Keywords: Climate policy, Nationally Appropriate Mitigation Actions, Transfer schemes

1 Introduction

The most recent round of negotiations under the United Nation Convention on Climate Change (UNFCCC) gave birth to the Copenhagen Accord. One of the main points of this document is to describe the expected role of Developing Countries (DCs) in the post-2012 climate regime (UNFCCC, 2009). The accord mainly focuses on three points: i) Greenhouse Gas (GHG) emissions peaking, ii) mitigation commitments and iii) funding and reporting. First, it recognizes that the time frame for GHG emissions peaking will be longer in Non-Annex I countries, since they will prioritize economic development and poverty eradication. Second, their mitigation efforts will be distinct from mitigation commitments of developed countries (Annex I under the UNFCCC), both in magnitude and in legal nature as stated in the Bali Action Plan (UNFCCC, 2007), since they will undertake NAMAs. Finally, NAMAs seeking foreign funding have to be registered and are subject to international Measurement, Reporting and Verification (MRV).

Following Kaul et al. (2003), we may think of NAMAs as a case of a global public good. The good would be the damages which are avoided by reducing GHG emissions. Its public good nature stems from the fact that no country may be excluded from the benefits of reducing GHG in any region of the planet. The adequate provision of this global public good depends, to a large extent, on the transfer scheme used to provide it. Thus, a key point for the functioning of NAMAs is the design of adequate transfers to allocate funding among Non-Annex I countries. Furthermore, there are two other main issues in NAMAs: (i) both the amount of the transfer and the envisaged level of mitigation efforts are voluntary declarations for countries, and (ii) the implementation of both an MRV system to corroborate financing and GHG reduction efforts may be a complex and not a politically neutral task. Therefore, well-designed transfer schemes are needed, which self-enforce the participation of countries, and thus improve the reduction of GHG emissions.

For the provision of a public good, the design of transfers has been essentially centered on schemes which help to reveal the true valuation that agents have of the public good (i.e., asymmetric information). One of the most important contributions in this field has been provided by Myerson and Sattertwhaite (1983). They show that there is no transfer scheme which simultaneously avoids asymmetric information:[1] it is individually rational, i.e., agents are not worse-off when participating; it is budget-balanced, i.e., total transfers are not negative; and it allows the (efficient) provision of the public good.

Two well-known transfer schemes which avoid asymmetric information are the *Clarke-Groves* (Clarke, 1971; Groves, 1973) and the *d'Aspremont-Gérard-Varet* mechanisms (d'Aspremont and Gérard-Varet, 1979). Emons (1994) analyzes the provision of environmental protection measures by means of these two mechanisms. He observes that *Clarke-Groves* transfers are not budget-balanced, and that under the *d'Aspremont-Gérard-Varet* transfers some agents are worse-off by participating. Miljkovic (2009) analyzes the provision of a global public good through the *Clarke-Groves* transfer. He corrects the budget-balance problem by setting up some conditions (e.g., by allowing participation only to countries with positive initial valuations on the public good). However, he determines that if there are countries which are pivotal for the provision of the good, i.e. - the good is not provided if they do not participate, then all the necessary conditions for such a mechanism cannot be satisfied.

For the case of global climate policies, Rose et al. (1998) propose transfer schemes for allocating GHG emission allowances among countries. More recently, Nagashima (2010) summarizes, in-depth, the alternative transfers employed in the literature to tackle global climate policies as well as the main results found due to their implementation, in particular to avoid free-riding. The transfers may be in the form of side payments, emissions permit trading or surplus sharing, and they have been mainly focused on one particular issue, namely the curtailing of free-rider incentives.

In this paper, we analyze the desirable features of transfers for NAMAs - i.e., *individually rational*, *budget-balanced*, anti-incentives for *free-riding* and *misrepresentation*. We model NAMAs as a non-cooperative, one shot game. Particularly, we analyze a NAMAs portfolio under two alternative transfers: a *horizontal equity-based* and a so-called "optimal" transfer which is a reformulation of a transfer proposed by Weikard (2009) which we

[1] A transfer scheme designed with the aim of avoiding asymmetric information is called *mechanism* by the literature of mechanism design problems.

call, hereafter, a transfer scheme *à la Weikard*. We think that these transfer schemes may be considered for the implementation of NAMAs in a post-2012 global climate policy since they include attractive ways to distribute surplus among countries to reduce GHG emissions. On the one hand, the *horizontal equity-based* transfer allocates the surplus payoff following an egalitarian rule (i.e., every participating country receives the same final payoff from avoiding climate change) and the transfer *à la Weikard* shares the surplus payoff in order to compensate the countries' outside payoffs (i.e., when free-riding). Though pursuing a similar objective, they differ in that the *horizontal equity-based* transfer, we observe, is a pragmatic transfer in the sense that it is the simplest way to distribute the surplus payof. On the other hand, the transfer *à la Weikard* is a more elaborate transfer and it is considered as an "optimal sharing rule" in the sense that it minimizes incentives to free-ride.

The main contributions of this paper are four: (i) we analyze NAMAs as a global public good in a game theoretical framework; (ii) we identify countries' behaviors (i.e., misrepresentation) and deviations from full cooperation (i.e., free-riding), (iii) we test for transfers that may alleviate these problems, and (iv) we study the role of pivotal countries. The remainder of this paper is organized as follows: Section 2 analyzes the NAMAs design problem; Section 3 examines the implementation of NAMAs by means of the *horizontal equity-based* transfer and a transfer *à la Weikard*; Section 4 illustrates our results via an illustrative example; and Section 5 draws some policy implications and concludes.

2 The NAMAs design problem

2.1 The model of a NAMAs portfolio: full cooperation

We propose to analyze a NAMAs portfolio as a contract among countries. We model the negotiation of such a contract as a non-cooperative,[2] one-shot game.[3] The set of players are countries $i = 1, 2, 3, \ldots, I$. which negotiate to participate in a NAMAs coalition. A NAMAs coalition may be formed as long as the coalition includes both Annex I and Non-Annex I countries. We refer to the case where all candidate countries sign the contract as the grand coalition G. Countries negotiate to cooperate in implementing a NAMAs portfolio for one economic sector or a nationwide program. The implementation of this NAMAs portfolio means that each DCs may propose one NAMAs program (its strategy) among a set of possible alternative programs. Note that in NAMAs, Annex I countries do not carry out mitigation activities. Then, the NAMAs program proposed by country i entails "national" (or sectoral) GHG emission reduction x_i.

For simplicity, we assume that x_i is the strategy of country i when it is called on to play. The total GHG emission mitigation (i.e., coalitional target) from the implementation of this NAMAs portfolio is given by $X_G = \sum_{i=1}^{I} x_i$. We further define the set of emissions as $\vec{X}_G = \{x_1, \ldots, x_I.\}$ with costs $C_G(\vec{X}_G) = \sum_{i=1}^{I} c_i(x_i)$.[4] We denote as $\overline{S}$ the volume of GHG emissions before NAMAs and by $\underline{S}$ the final volume of GHG emissions after the

[2] Games may be also designed in a cooperative way. For an example of solution for the design of cooperative environmental agreements, see for instance, Chander and Tulkens (1995).

[3] The model described in this section should be applied, in principle, to other types of situations than NAMAs. For instance, in the design of a global climate policy centered on GHG mitigations.

[4] We consider that countries may propose "no-regret options" (i.e., mitigation opportunities with net negative costs).

implementation of the NAMAs portfolio, so that $X_G = \overline{S} - \underline{S}$.[5] We consider that NAMAs are implemented as a complement of a post-2012 global climate policy (e.g., at least a Kyoto forever scenario). We assume that mitigation actions which are carried out by Non-Annex I countries through the Clean Development Mechanism (CDM) and financed by the Global Environmental Facility (GEF) are not included in the NAMAs portfolio.[6] Note that there is no burden-sharing rule to distribute GHG abatement among participating Non-Annex I countries as NAMAs is a voluntary declaration for them.

We assume that countries are not identical. They differ in two parameters: abatement costs and willingness to pay for the NAMAs portfolio. Developed countries do not incur costs because they take part uniquely by financing NAMAs. Note that NAMAs portfolios may not lead to Pareto optimal outcomes since all Non-Annex I countries are asked (as under the Copenhagen accord) to carry out mitigation activities regardless of their marginal abatement costs. Thus, countries may propose other x_i different to their efficient solution, i.e., where marginal costs and benefits from abatement are equal[7]. Countries reveal their willingness to pay for the NAMAs portfolio $\theta_i(X_G)$, which is increasing in X_G. We assume that this parameter is a direct measure of the damages $D_i(X_G)$ which are avoided by reducing X_G. Country i perceives with the implementation of the NAMAs portfolio, an environmental gain $\theta_i(X_G) \equiv D_i(\overline{S}) - D_i(\underline{S})$, with $D_i(\overline{S})$ as damages expected if the NAMAs portfolio does not occur and $D_i(\underline{S})$ as damages expected if the NAMAs portfolio occurs.[8] Then, the total environmental gain from the implementation of the NAMAs portfolio is $\Theta_G(X_G) = \sum_{i=1}^{I} \theta_i(X_G)$, and $\vec{\Theta}(X_G) = \{\theta_1(X_G), \ldots, \theta_I(X_G).\}$. We denote $\widehat{v}_{i\in G}(\cdot)$ as the initial payoff for country i and it is defined as follows: $\widehat{v}_{i\in G}(X_G, x_i) = \theta_i(X_G) - c_i(x_i)$. We allow countries to make transfers $t_i \in \Re$ among them. If $t_i > 0$ country i contributes with the financing of NAMAs programs abroad, otherwise it receives a subsidy to carry out its NAMAs program. The sum of total transfers is denoted by $T = \sum_{i=1}^{I} t_i$, with $\vec{T} = \{t_1, \ldots, t_I.\}$. Country i receives the following final payoff if it participates in the coalition:

$$v_{i\in G}(X_G, x_i, t_i) = \theta_i(X_G) - c_i(x_i) - t_i. \tag{1}$$

Countries cooperate freely in the implementation of a NAMAs portfolio. We expect that a minimum requirement for a country i to cooperate is that it receives, at least, an equal final payoff than in the *status quo*.[9] Thus, we state that cooperation must be *individ-*

These options have benefits such as reduced energy costs and reduced emissions of local/regional pollutants which equal or exceed their costs to society, excluding the benefits of avoided climate change (IPCC, 2007). Bottom-up studies suggest that mitigation opportunities with net negative costs have the potential to reduce emissions by about 6 $GtCO_2$-eq/yr in 2030 (IPCC, 2007).

[5] We do not consider decay rate effects for these GHG emissions.

[6] The GEF supports projects in Non-Annex I countries that reduce or avoid GHG emissions in the areas of renewable energy, energy efficiency, and sustainable transport.

[7] One rationale for our assumption is that, for instance, the level of GHG reduction targets agreed under the Kyoto protocol was set up regardless of cost-benefit analysis. For a discussion on the cost inefficiency of targets under the Kyoto protocol, see McKibbin and Wilcoxen (2002).

[8] In this paper, we do not consider that countries could benefit from climate change (i.e., $\theta_i(X_G) < 0$). We base our assumption on the fact that NAMAs is a policy instrument focused on Non-Annex I countries and that the impact of climate change on these countries is expected to be negative, particularly larger than that for developed countries for 4° of warming (IPCC, 2007).

[9] We define as *status quo*, the case where there is not abatement reduction at all due to the implementation of a NAMAs portfolio, that is $\theta_i(0) = 0$.

ually rational and the following condition be upheld:

(i) The final payoff of every country is non-negative: $v_{i\in G}(X_G, x_i, t_i) \geq 0, \forall i$.

We assume that there is no source of funds (beyond countries' transfers) to finance a NAMAs portfolio. One rationale for that is the current scarcity of international funds to provide a global public good. Therefore, we consider that a NAMAs portfolio is *budget-balanced* if the following condition is satisfied:

(ii) Total transfers are not negative: $T \geq 0$.

In addition, we consider that a necessary requisite for the implementation of a NAMAs portfolio is the following *feasibility condition*:

(iii) The total environmental gain equals or exceeds total cost: $\Theta_G(X_G) \geq C_G(\vec{X}_G)$.

We comprehend (iii) from the *efficient provision decision rule* of a discrete public good stated firstly by Samuelson (1954). There, the public good should be provided if the sum of consumers' reservation prices exceeds the cost of providing the public good, otherwise the *status quo* should be kept. In our analysis, the public good (i.e., avoided impacts from reduction in GHG emissions) may be considered as a continuous public good since the total GHG mitigation potential $\vec{X}_G$ depends on how many countries i take part in coalition G. Note that (i) and (ii) entail (iii). By (i), we obtain the result that $v_{i\in G}(X_G, x_i, t_i) \geq 0$, then $\sum_{i=1}^{I} v_{i\in G}(X_G, x_i, t_i) \geq 0$ which is the same as $\Theta_G(X_G) - C_G(\vec{X}_G) - T \geq 0$; and by (ii), $T \geq 0$, then necessarily $\Theta_G(X_G) - C_G(\vec{X}_G) \geq 0$.

Definition 1. *A NAMAs coalition G is individually rational, balanced and feasible if there is, at least, one set $\{\vec{X}, \vec{T}\}$ that meets conditions (i), (ii), and (iii) $\forall i \in G$.*

We found, in the literature, that the existence is possible of pivotal agents for the provision of a public good (Clarke, 1971; Groves, 1973). More recently, Miljkovic (2009) again takes up this concept for the case of the provision of a global public good. He glimpses the possible presence of pivotal countries within international organizations. We consider it useful to study the role of pivotal countries in the implementation of NAMAs.

Let $\Theta_{G-j}(X_{G-j})$ and $C_{G-j}(\vec{X}_{G-j})$, be the total willingness to pay and the total cost of coalition G without country j, respectively, with $X_{G-j} = X_G - x_j$ and $C_{G-j}(\vec{X}_{G-j}) = C_G(\vec{X}_G) - c_j(x_j)$ and $\Theta_{G-j}(X_{G-j}) = \sum_{i=1}^{I} \theta_{i\notin j}(X_{G-j})$.[10]

Definition 2. *Assume that the grand coalition G is formed and that (iii) holds. Then, j is a pivotal country if when j withdraws from G, (iii) does not hold anymore (pivotal effect):*[11]

$$\Theta_{G-j}(X_{G-j}) - C_{G-j}(\vec{X}_{G-j}) < 0. \tag{2}$$

[10] Thereafter, we denote as j a country which is the only one having a different behavior compared to the other countries $i \in G$.

[11] This condition may not be associated with the non-essentiality definition of Weikard (2009). There, a player j is non-essential for a coalition if, whether j takes part or not in the coalition, no country has an incentive to withdraw from the coalition. Following our pivotal definition, it should be the case that a non-pivotal country might be essential or not essential for the coalition.

A pivotal country is necessarily one for which $\theta_j(X_G) >> c_j(x_j)$. Note that country j may be both an Annex I country or a DCs - e.g., Annex I countries with high benefits from avoiding GHG emissions and Non-Annex I countries with low marginal abatement costs and high benefits. For the purposes of this paper, we classify the national NAMAs programs, as described in the Copenhagen Accord (UNFCCC, 2009), into two categories: (i) unilateral NAMAs that are self-financed actions undertaken by Non-Annex I countries, and (ii) supported NAMAs that are programs which need some monetary transfer from developed countries.

2.2 Countries' behaviors and deviations from full cooperation

Unfortunately, finding a set $\{\vec{X}, \vec{T}\}$ that meets (i) to (iii) is not enough to guarantee that countries will fully cooperate when implementing a NAMAs. There are some issues such as free-riding and asymmetric information that may still doom to failure the implementation of a NAMAs portfolio as in definition (1). In the following, we analyze how these issues may act under a NAMAs portfolio and we propose some conditions which help in dealing with them.

2.2.1 Anti-free-rider incentives

Cooperation on GHG mitigation is plagued by free-riding since the output of mitigation activities can be viewed as a global public good.[12] Therefore, it would be expected that NAMAs will have to deal with this problem. As participation of Non-Annex I countries is voluntary, they should base their decision to participate in NAMAs on their payoffs when participating in coalition G (i.e., equation 1) and when remaining outside and enjoying the benefits of the avoided GHG mitigation efforts made by the other countries (i.e., free-riding). In the free-riding case, equation (1) becomes:

$$v_{j \notin G}(X_{G-j}, 0, 0) = \theta_j(X_{G-j}). \tag{3}$$

Note that the outside payoff $\theta_j(X_{G-j})$ of a country j when it is pivotal for the implementation of a NAMAs portfolio is zero since $X_{G-j} = 0$. We introduce the *no-free-rider incentive condition* into the analysis by substituting (3) in (i). Then, we state the following:

(iv) No country is better-off when free-riding: $v_{j \in G}(X_G, x_j, t_j) \geq \theta_j(X_{G-j}), \forall j$.

Note that (iv) is a stricter version of (i). If there is a coalition G that holds with (iv) for all countries, then coalition G is internally stable (hereafter stable) - i.e. no country has an incentive to withdraw from the coalition.[13] In consequence, the coalition G constitutes

[12] For a game theoretical survey of this problem in international cooperation on climate change agreements, see for instance Böhringer et al. (2002). For some policy implications related to free-riding in climate change negotiations see Banuri et al. (2001).

[13] In this paper, we only search for internally stable coalitions as G is the grand coalition. However, in related studies, the externally stable concept is also employed: a coalition is externally stable if no non-participating country has an incentive to joint the coalition (d'Aspremont et al., 1983; Nagashima et al., 2009).

a Nash equilibrium and the NAMAs portfolio is self-enforcing.[14] We have two situations when analyzing anti free-rider incentives: one for pivotal countries and other for non-pivotal countries.

Proposition 1. *If (i) to (iii) are fulfilled, and j is pivotal, then (iv) always holds for country j.*

Proof. If country j is a pivotal DCs, and it leaves the coalition G, then the NAMAs portfolio is not implemented at all and its final payoff from free-riding is zero, and by (i) $v_{j\in G}(X_G, x_j, t_j)$
≥ 0, (iv) (weakly) holds and j has no incentives to free-ride. ■

Proposition 1 implies that (i) is necessary and sufficient for pivotal countries. However, if j is a non-pivotal DCs, j decides to take part in the coalition if and only if it satisfies (iv). Therefore, if we have a feasible set $\{\vec{X}, \vec{T}\}$ which holds with (ii) and (iv) for all i, then coalition G is balanced, individually rational, avoids free-rider incentives and by consequence is efficient at providing the public good - i.e., X_G is provided.

If (iv) does not hold for a non-pivotal country j, the Nash equilibrium is that j free-rides and the NAMAs portfolio is carried out by coalition $G - j$. This result is in line with that found by Nagashima et al. (2009). They study the impact of transfer on the incentives for regions to join international climate agreements. They find that no transfer is capable of stabilizing the participation of all countries, but an optimal sharing surplus rule proposed by Weikard (2009) allows the formation of larger stable coalitions which include key players. Therefore, in section 3, we test the transfer *à la Weikard* to the case of NAMAs.

2.2.2 Asymmetric information

Asymmetric informational problems have been reported in the contract design of payments for environmental services (Ferraro, 2008). There are two important information asymmetries in the design of contracts: hidden information (i.e., adverse selection) and hidden action (i.e., moral hazard).[15] Labbate (2008) analyzes adverse selection problems in the application of the Incremental Costs (IC) principle for the conservation of global habitats by the GEF.[16] As the calculation of the IC requires the estimation of benefits and costs in two distinct scenarios (baseline and counterfactual), there are incentives to the recipient countries to misrepresent their costs and benefits from the project, and therefore receive higher IC transfers.

For the case of global climate policy, asymmetric informational problems have been studied in joint implementation (Hagem, 1996) and CDM projects (Millock, 2002). Hagem (1996) considers that countries may have two kinds of private information on efficiency, and on actions taken during the project period. Millock (2002) considers that Non-Annex

[14] We do not consider (iv) for developed countries as their participation is mandatory in NAMAs.

[15] For a comprehensive theoretical framework on asymmetric information, see, for example, Bolton and Dewatripont (2005).

[16] IC is the extra cost that a country incurs when contributing to a global public good in an amount greater than it would have contributed if it had been guided solely by criteria of national interest. The country that undertakes the extra effort receives a compensation payment (King, 2006).

I countries possess private information on a technical efficiency parameter (i.e., they may exaggerate their emission reduction costs in order to receive a larger transfer).

In this context, for the case of NAMAs, the initial payoff of countries $\widehat{v}_{j\in G}$ may not be observable or available public information since each country should know their costs better than the others $c_j(x_j)$ and benefits $\theta_j(X_G)$ associated with the implementation of a NAMAs portfolio. Then, countries may misrepresent their types by either overestimating costs $\widetilde{c}_j(x_j)$ or underestimating benefits $\widetilde{\theta}_j(X_G)$, and in consequence they may get an "informational rent". Thus, we state the following *incentive compatibility condition* for NAMAs:

(v) No country misrepresents its type if: $v_{j\in G}(X_G, x_j, t_j) \geq v_{j\in G}(X_G, x_j, \widetilde{t}_j) \forall j$.

With some abuse of the notation in (v), we let $\widetilde{t}_j$ be the transfer that country j makes when it announces either $\widetilde{\theta}_j(X_G)$ or $\widetilde{c}_j(x_j)$.

Finally, an ideal contract for the implementation of a NAMAs portfolio has to guarantee five requirements: it is individually rational, condition (i); it is budget-balanced, condition (ii); it is feasible, condition (iii); it avoids free-riding, condition (iv); and it is incentive compatible, condition (v). An important role in such a contract is played by the transfer schemes employed to implement the NAMAs portfolio. Therefore, we focus in the next section on transfer schemes for NAMAs.

3 Transfer schemes for NAMAs

Transfers have recently attracted the attention of the literature on global climate agreements since they are seen as efficient instruments to target climate change directly. They have been mainly associated with the flow of resources from developed countries to DCs (Frankel, 2007; Höhne et al., 2006; Reinstein, 2004; Sugiyama and Sinton, 2005). Rose et al. (1998) investigate the impact of transfers for allocating emissions permits. They classify transfers into two types: allocation-based rules, i.e., permits are initially distributed among countries according to certain criteria, and outcome-based rules, i.e., net benefits from cooperative abatement efforts are distributed among countries based on certain criteria. More recently, Nagashima (2010) summarizes, in-depth, the alternative transfers employed in the literature to tackle global climate policies as well as the main results found due to their implementation. She points out that the design and analysis of transfers among countries in the form of side payments, emissions permit trading or surplus sharing has been mainly focused on one particular issue, namely the curtailing of free-rider incentives. For our analysis, we consider it appropriate to state the following set of definitions.

Definition 3. *A transfer for NAMAs $t_i(X_G, x_i)$ is a sharing rule of distributing the total initial payoff $\sum_{i=1}^{I} \widehat{v}_{i\in G}(X_G, x_i)$ of countries $i \in G$ such that conditions (i) and (ii) are fulfilled.*

Definition 4. *The transfer $t_i(X_G, x_i)$ provides an anti-free-rider incentive and it is considered as efficient if it allows (iv) to be fulfilled $\forall i \in G$, in consequence $\vec{X}_G$ is reached.*

A transfer that deals with asymmetric informational problems is considered as a *mechanism* by the literature of *mechanism design problem* (Mas-Colell et al., 1995). Therefore, in order to continue with this well-established definition, we consider it necessary to make the difference between a *transfer* and a *mechanism*.

Definition 5. *A transfer for NAMAs $t_i(X_G, x_i)$ is a* mechanism *if and only if it is efficient and it allows (v) to be fulfilled.*

Definition 5 states, then, that the main goal of a *mechanism* is to deal with asymmetric information. A *mechanism* may be viewed as an *institution* or a *center* which governs the procedure for making the collective choice. This *center* is completely informed about the type that each country is and it has the possibility to "arrange" the game so that countries receive the best final payoff when telling the truth.

Armed with these definitions, an ideal transfer for NAMAs would be a *mechanism* that meets conditions (i) to (v). However, we know by the **Myerson-Sattertwhaite** impossibility theorem (Myerson and Sattertwhaite, 1983) that, in general, there is not a *mechanism* that is individually rational, condition (i); it is budget-balanced, condition (ii); it makes possible the provision of a public good, condition (iii); and it avoids misrepresentation, condition (v) when participation is voluntary. Moreover, Emons (1994) shows, for example, that the set of conditions (i) to (iii) do not always hold simultaneously for the well-known *mechanisms* employed for the provision of a public good under private information, namely, the *Clarke-Groves* and the *d'Aspremont-Gérard-Varet* mechanisms. He observes that *Clarke-Groves* transfers are not budget-balanced (i.e., the sum of transfers is negative). This failure may be avoided by the *d'Aspremont-Gérard-Varet* transfer; however, in this one, participation of some agents may not be individually rational.

Transfers under the *Clarke-Groves mechanism* depend on the effect that countries impose on the coalition with its participation (Clarke, 1971; Groves, 1973). For the case of a NAMAs portfolio, the *Clarke-Groves mechanism* may be stated as $t_i^{CG}(\cdot) = \sum_{j=1, j\neq i}^{I} \widehat{v}_{j\in G}(X_{G-i}, x_j) - \sum_{j=1, j\neq i}^{I} \widehat{v}_{j\in G}(X_G, x_j)$. Looking on the right-hand side, the first term represents the effect that country i imposes to all other countries in the coalition when it does not participate, and the second term is the effect that i imposes to all other countries with its participation. Under this transfer scheme, i's transfer is zero if when it reveals its type, it does not change the decision of providing the public good (e.g., NAMAs). Otherwise, it receives a transfer, and in that case i is pivotal for the provision of the public good. Thus, the sum of transfers is obviously negative. Several studies have shown that the *Clarke-Groves mechanism* is not budget-balanced, see for instance, Emons (1994). As a result, it is not a transfer for NAMAs, as we state in definition 3.

Under the *d'Aspremont-Gérard-Varet mechanism*, a country's transfer is based on the expected value of the other countries' initial payoffs depending on its own (d'Aspremont and Gérard-Varet, 1979). It may be denoted for NAMAs as $t_i^{AGV}(\cdot) = \xi_i \left[\widetilde{\widehat{v}}_i(\cdot), \widehat{v}_j(\cdot)\right] - \frac{1}{(I-1)} \sum_{j=1}^{I} \xi_{j\neq i} \left[\widetilde{\widehat{v}}_j(\cdot), \widehat{v}_i(\cdot)\right]$.[17] This *mechanism* assumes that the parameter containing private information, in our case $\widehat{v}_i(\cdot)$ is not known by country i before participation. Looking on the right hand side, the first term represents the sum of j's expected payoff when country i announces a $\widetilde{\widehat{v}}_i(\cdot)$; and the second term is a contribution that country i makes to each

[17] ξ_i is an expectational term. For a mathematical explanation of its meaning, see Mas-Colell et al. (1995), page 886.

other $I-i$ country when it states the truth.

This mechanism is budget-balanced since $\sum_{i=1}^{I} t_i^{AGV}(\cdot) = \sum_{i=1}^{I} \xi_i[\cdot] - \frac{1}{(I-1)} \sum_{i=1}^{I} (I-1)\xi_i[\cdot] = 0$. However, under this mechanism, it is possible that some countries have to pay a $t_i^{AGV} > \widehat{v}_i(\cdot)$. Thus, if these countries know in advance their types $\widehat{v}_i(\cdot)$ but they do not know the other agents' types, they will not have an incentive to participate when they are obligated to state the truth, since substituting the *d'Aspremont-Gérard-Varet* transfer in (1), we conclude by condition (i), $v_i(X_G, x_i, t_i^{AGV}) < 0$. Thus, the *d'Aspremont-Gérard-Varet* is not a transfer for NAMAs, as we state in definition 3.

We have just shown that even when condition (iii) holds, conditions (i) and (ii) are not necessarily fulfilled. Therefore, as these time-honored mechanisms employed for the provision of a public good do not meet the minimal requirements for the implementation of a NAMAs portfolio, we restrict thereafter our attention only to transfers that meet definition 3. Then, we check their efficiency in the provision of NAMAs (definition 4) to see whether they could be employed as mechanisms (definition 5). We particularly analyze NAMAs under two alternative transfers: a *horizontal equity-based* transfer and a transfer *à la Weikard*. Although both transfers are of the type of surplus sharing, they differ in that the *horizontal equity-based* transfer distributes the surplus payoff following an egalitarian rule (i.e., every participating country receives the same final payoff from avoiding GHG emissions); and the transfer *à la Weikard* shares the surplus payoff in order to compensate the countries' outside payoffs (i.e., when free-riding). Furthermore, they differ in that the *horizontal equity-based* transfer is a pragmatic transfer in the sense that it is the simplest way to distribute the surplus payoff, whereas the transfer *à la Weikard* is a more elaborated transfer and it is considered to be an "optimal sharing rule".

3.1 A horizontal equity-based transfer scheme

We propose the following *horizontal equity-based* transfer scheme for NAMAs:

$$t_i^H(X_G, x_i) = \widehat{v}_{i\in G}(X_G, x_i) - \frac{\sum_{j=1}^{I} \widehat{v}_{j\in G}(X_G, x_j)}{I}. \tag{4}$$

This transfer follows a distribution rule for the surplus payoff that allows all participating countries to receive an equalized final payoff. This *horizontal equity-based* transfer follows the idea of the horizontal outcome-based equity criterion for global climate policy described by Rose et al. (1998). They define this criterion for the distribution of tradable CO_2 emission permits, where all countries are treated equally. Its main operational rule is to equalize net welfare change across nations.

Proposition 2. *If (iii) holds and $\vec{T}$ follows (4), then (ii) and (i) also hold.*

Proof. For (ii), substituting (4) in (ii), we see:
$\sum_{i=1}^{I} t_i^H(X_G, x_i) = \sum_{i=1}^{I} \left[\widehat{v}_{i\in G}(X_G, x_i) - \frac{\sum_{j=1}^{I} \widehat{v}_{j\in G}(X_G, x_j)}{I} \right] = 0.$
For (i), the final payoff of country i when it takes part in the grand coalition G may be calculated substituting (4) in (1). That is:

$v_{i\in G}(X_G, x_i, t_i^H) = \frac{\sum_{i=1}^{I} \widehat{v}_{i\in G}(X_G, x_i)}{I} = \frac{\Theta_G(X_G) - C_G(\vec{X}_G)}{I} \geq 0$, by (iii).

■

We analyze free-rider incentives under this *horizontal equity-based* transfer (4) for a non-pivotal country j when conditions (i) to (iii) hold. Substituting (4) in (1), we can rewrite (iv) as follows:

$$\frac{\Theta_G(X_G) - C_G(\vec{X}_G)}{I} \geq \theta_j(X_{G-j}). \tag{5}$$

From (5) we state that a non-pivotal country j which receives lower environmental gains from the mitigation of other coalition members than the average initial payoffs has an incentive to remain in the grand coalition. Otherwise, j free-rides and coalition $G - j$ is formed.

Now consider misrepresentation incentives for country j. As analyzed in section 2.2.2, countries may misrepresent $\widehat{v}_{j\in G}(X_G, x_j)$. Then, if country j overestimates mitigation costs by announcing a $\widetilde{c}_j(x_j) > c_j(x_j)$, then (4) becomes:

$$\widetilde{t}_j^H(X_G, x_j) = \theta_j(X_G) - \widetilde{c}_j(x_j) - \frac{\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - \widetilde{c}_j(x_i)}{I}. \tag{6}$$

We find, by rewriting (v), that this country will not have incentives to misrepresent its type if $v_{j\in G}(X_G, x_j, t_j^H) - v_{j\in G}(X_G, x_j, \widetilde{t}_j^H) \geq 0$. We rewrite the final payoff of country j if it tells the truth as $\frac{\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - c_j(x_j)}{I}$ (see proof of proposition 2); and by substituting (6) in (1), we find that the final payoff of country j when it announces $\widetilde{c}_j(x_j)$ is $\widetilde{c}_j(x_j) - c_j(x_j) + \frac{\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - \widetilde{c}_j(x_j)}{I}$. Then, $v_{j\in G}(X_G, x_j, t_j^H) - v_{j\in G}(X_G, x_j, \widetilde{t}_j^H) = \left[\widetilde{c}_j(x_j) - c_j(x_j)\right] \frac{1-I}{I} < 0$. As a result, country j has an interest to overstate its mitigation costs.

The same analysis may be done when j understates its benefits by announcing $\widetilde{\theta}_i(X_G) < \theta_i(X_G)$. There, (4) becomes:

$$\widetilde{t}_j^H(X_G, x_j) = \widetilde{\theta}_j(X_G) - c_j(x_j) - \frac{\Theta_{G-j}(X_G) + \widetilde{\theta}_j(X_G) - C_G(\vec{X}_G)}{I}. \tag{7}$$

We rewrite the final payoff of country j when stating the truth as $\frac{\Theta_{G-j}(X_G) + \theta_j(X_G) - C_G(\vec{X}_G)}{I}$. Substituting (7) in (1), we find that the final payoff of country j when misrepresenting its environmental gain is $\theta_j(X_G) - \widetilde{\theta}_j(X_G) + \frac{\Theta_{G-j}(X_G) + \widetilde{\theta}_j(X_G) - C_G(\vec{X}_G)}{I}$. Then:

$$\begin{aligned} v_{j\in G}(X_G, x_j, t_j^H) - v_{j\in G}(X_G, x_j, \widetilde{t}_i^H) &= \frac{\theta_j(X_G) - \widetilde{\theta}_j(X_G)}{I} - \theta_j(X_G) + \widetilde{\theta}_j(X_G) \\ &= \frac{1-I}{I}\left[\theta_j(X_G) - \widetilde{\theta}_j(X_G)\right] < 0. \end{aligned}$$

Again, country j gains from misreporting its type.

In summary, the *horizontal equity-based* transfer scheme is individually rational and balanced. However, it does not avoid free-riding for all types of countries, preventing the formation of the grand coalition and in consequence not reaching the coalitional target X_G. Thus, it is not efficient. Moreover, it is not incentive compatible, since coalition members are better-off either over-reporting their mitigation costs or understating their environmental benefits, and as a result it may not be considered as a mechanism (definition 5).

3.2 An "optimal" transfer scheme à la Weikard

Nagashima et al. (2009) found that an optimal sharing surplus transfer was the best at avoiding free-rider incentives and stabilizing climate coalitions. Optimal sharing surplus transfers have been suggested by Carraro et al. (2006); McGinty (2007); Weikard (2009); Fuentes-Albero and Rubio (2010). In this paper, we consider the implementation of NAMAs based on Weikard (2009). Thus, we establish the following transfer *à la Weikard*:[18]

$$t_j^W\,(X_G,x_j) = \widehat{v}_{j\in G}(X_G,x_j) - \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \times \sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G,x_i). \tag{8}$$

Weikard (2009) proposes to share the surplus payoff following a rule where the coalition surplus is distributed proportional to outside option payoffs (See equation 3). The term $\sum_{k=1}^{I}\theta_k(X_{G-k})$ is the total of outside option payoffs. Weikard transfers more benefit to countries with the highest outside option payoff.

Proposition 3. *If (iii) holds and $\vec{T}$ follows (8), then (ii) and (i) also hold.*

Proof. For (ii), substituting (8) in (ii), we see:

$$\begin{aligned}\sum_{j=1}^{I} t_j^W\,(X_G,x_j) &= \sum_{j=1}^{I}\left[\widehat{v}_{j\in G}(X_G,x_j) - \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \times \sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G,x_i)\right] \\ &= \sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G,x_i) - \frac{\sum_{j=1}^{I}\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \times \sum_{i=1}^{I}\widehat{v}_{i\in G}(X_G,x_i) = 0.\end{aligned}$$

For (i), the final payoff of country j when it takes part in the grand coalition G may be calculated substituting (8) in (1):

[18] We have changed the order of terms in the original formula with the aim of aligning it with the meaning of the sign we employ in our model: $t_i(\cdot) > 0$, country i contributes to finance NAMAs abroad, otherwise it is a transfer recipient.

$$\begin{aligned} v_j(X_G,x_j,t_j^W) &= \widehat{v}_{j\in G}(X_G,x_j) - t_j^W\ (X_G,X_{G-j},x_j) \\ &= \sum_{i=1}^{I} \widehat{v}_{i\in G}(X_G,x_i) \times \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \\ &= \left[\Theta(X_G) - C_G(\vec{X}_G)\right] \times \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \geq 0. \end{aligned}$$

If $\Theta_G(X_G) = C_G(\vec{X}_G)$, then $v_j(X_G,x_j,t_j^W) = 0$. For the case when $\Theta_G(X_G) > C_G(\vec{X}_G)$; pivotal countries have $\theta_j(X_{G-j}) = 0$, by proposition 1, and they then receive a final payoff $v_j(X_G,x_j,t_j^W) = 0$; and non-pivotal countries receive $v_j(X_G,x_j,t_j^W) > 0$ as a final payoff. ■

Now consider free-rider incentives for non-pivotal countries under the transfer *à la Weikard*. We can rewrite (iv), by substituting (8) in (1), as follows:

$$\left[\Theta_G(X_G) - C(\vec{X}_G)\right] \times \frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})} \geq \theta_j(X_{G-j}), \tag{9}$$

which is the same as:

$$\Theta_G(X_G) - C(\vec{X}_G) \geq \sum_{k=1}^{I}\theta_k(X_{G-k}). \tag{10}$$

As proved above, if (ii) holds for (8), then pivotal countries pay a transfer equivalent to $t_j^W(X_G,x_j) = \widehat{v}_{j\in G}(X_G,x_j)$, and all surplus payoff, if any, is allocated to non-pivotal countries. From (9) or (10), we conclude that when the surplus payoff exceeds or equals the total of outside option payoffs of non-pivotal countries, no non-pivotal country k has an incentive to free-ride, and the grand coalition formed is stable. When (10) holds, Weikard (2009) states that the coalition G is potentially self-enforcing (stable).

We analyze whether when G is formed with transfers *à la Weikard*, signatory countries would have incentives to misrepresent their types. They can do this by overstating their mitigation costs or understimating their environmental gains. For notational ease, we define $b_j = \left(\frac{\theta_j(X_{G-j})}{\sum_{k=1}^{I}\theta_k(X_{G-k})}\right)$. Country j would misrepresent its type by, for instance, over-reporting its mitigation costs $\widetilde{c}_j(x_j) > c_j(x_j)$,[19] then (8) becomes:

$$\widetilde{t}_j^W\ (X_G,x_j) = \theta_j(X_G) - \widetilde{c}_j(x_j) - \left[\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - \widetilde{c}_j(x_j)\right] b_j. \tag{11}$$

Substituting (11) in (1), we find that the final payoff of country j when over-reporting its mitigation costs is $\widetilde{c}_j(x_j) - c_j(x_j) + b_j\left[\Theta_G(X_G) - C_{G-j}(\vec{X}_{G-j}) - \widetilde{c}_j(x_j)\right]$. Then, the incentive compatibility condition (v) does not hold as $v_{j\in G}(X_G,x_j,t_j^W) - v_{j\in G}$

[19] We do not analyze $\widetilde{c}_j(x_j)$ if j is a developed country since it does not incur any mitigation costs.

$(X_G, x_j, \widetilde{t}_j^W) = \left[c_j(x_j) - \widetilde{c}_j(x_j)\right](1 - b_j) < 0$. Note that $0 \le b_j \le 1$. If $b_j = 0$, then j is pivotal and if $b_j = 1$, then there is only one country and it is non-pivotal. Therefore, country j has an interest to overstate its mitigation costs.

When country j under-reports its environmental gain $\widetilde{\theta}_j(X_G) < \theta_j(X_G)$, (8) becomes:[20]

$$\widetilde{t}_j^W\ (X_G, x_j) = \widetilde{\theta}_j(X_G) - c_j(x_j) - \left[\Theta_{G-j}(X_G) + \widetilde{\theta}_j(X_G) - C_G(\vec{X}_G)\right] b_j. \quad (12)$$

Substituting (12) in (1), we deduce that the final payoff of country j when it announces $\widetilde{\theta}_j(X_G)$ is $\theta_j(X_G) - \widetilde{\theta}_j(X_G) + \left[\Theta_{G-j}(X_G) + \widetilde{\theta}_j(X_G) - C_G(\vec{X}_G)\right] b_j$. Then, the incentive compatibility condition (v) does not hold as $v_{j\in G}(X_G, x_j, t_j^W) - v_{j\in G}(X_G, x_j, \widetilde{t}_j^W)$ $= \left[\widetilde{\theta}_j(X_G) - \theta_j(X_G)\right](1 - b_j) < 0$. Once more, country j gains from misreporting.

In conclusion, the transfer scheme *à la Weikard* is balanced, individually rational and allows the formation of the grand coalition if the surplus payoff covers the total of outside option payoffs of non-pivotal countries. Thus, it is efficient at providing the public good, X_G. However it is not incentive compatible because countries may misrepresent their true types; consequently it may not be defined as a mechanism (definition 5).

4 NAMAs under an illustrative example

In this section, we describe NAMAs through an illustrative example. We analyze the case of full cooperation as well as free-riding and misrepresentation problems for both the *horizontal equity-based* and the transfer *à la Weikard*. Consider the negotiation of a NAMAs portfolio by four countries $I = \{A, B, C, D\}$. Country A is a developed country. Countries B, C and D are Non-Annex I countries. They are different in three points, namely: the income measured through the Gross Domestic Product $(\text{GDP})_i$, GHG emission reduction x_i, and marginal abatement costs $c\prime_i$ of reducing GHG emissions. Countries have linear abatement costs, so that $c_i(x_i) = c\prime_i x_i$. We assume that the following inequalities hold for these Non-Annex I countries: $\text{GDP}_A > \text{GDP}_B > \text{GDP}_C > \text{GDP}_D, x_B > x_C > x_D$, and $c\prime_B < c\prime_C < c\prime_D$. For simplicity, we consider that the GHG emission reduction target is $X_G = 20$ units, with $X_G = x_b + x_c + x_d$.

We estimate damages which are avoided by reducing these 20 units as an arbitrary proportion of GDP_i, i.e., $\theta_i(X_G) = \theta_i(20) = \frac{1}{9}\text{GDP}_i$. As θ_i is increasing in X, then $\theta_i(X_G) > \theta_i(X_{G-c}) > \theta_i(X_{G-d})$, where $X_{G-i} = X_G - x_i$ for $i = C, D$. Let us choose a set $\{\vec{X}, \vec{T}\}$ which satisfies these properties: (a) that condition (iii) holds; (b) that country B carries out a unilateral NAMAs program as $\theta_i(X) > c_i(x_i)$; (c) that country C undertakes a partially supported NAMAs as $\theta_i(X) < c_i(x_i)$; (d) that country D embarks on a *quasi* fully supported NAMAs as $\theta_i(X) << c_i(x_i)$; and (e) that countries A & B are pivotal. Table 1 shows a set of values $(x_i, \text{GDP}_i, c\prime_i)$ that satisfy all these assumptions. Remember that $\widehat{v}_i(X_G, x_i) = \theta_i(X_G) - c_i(x_i)$, and it is the initial payoff of country i.

[20] In this study, we do not consider the possibility that country j does misrepresent its type $\theta_j(X_{G-j})$.

Table 1: Data for the illustrative example.[a]

Parameter	Country A	Country B	Country C	Country D	Total
GDP_i	320.00	225.00	45.00	5.00	595.00
x_i	[b]	10.44	8.00	1.55	20.00
$c\prime_i$	[b]	2.00	4.00	6.00	-
$c_i(x_i)$	[b]	20.88	32.00	9.33	62.22
$\theta_i(X_G)$	35.55	25.00	5.00	0.55	66.11
$\widehat{v}_i(X_G,x_i)$	35.55	4.12	-27.00	-8.78	3.89
$\theta_i(X_{G-c})$[c]	18.82	13.24	2.65	0.29	32.35
$\theta_i(X_{G-d})$[d]	33.68	23.68	4.74	0.53	62.11

Notes:

[a] All figures are given in the same numeration (u).

[b] As country A is a developed country, these values are not needed for our calculation.

[c] We assign $\theta_i(12) = (1/17)\mathrm{GDP}_i$.

[d] We assign $\theta_i(18.44) = (1/9.5)\mathrm{GDP}_i$.

4.1 The horizontal equity-based transfer scheme

We apply to this feasible set the *horizontal equity-based* transfer. Table 2 shows the results for full cooperation, free-riding and misrepresentation that we analyze in section 3.1. Note that proposition 2 holds since the total sum of transfers is zero (ii), and that transfers guarantee that every country receives a positive final payoff (i). The surplus payoff is distributed in an egalitarian way. Countries A & B pay for NAMAs in other countries, whereas countries C & D receive transfers to undertake their NAMAs.

When we consider anti free-rider incentives, we have the following results: (a) that pivotal countries A & B do not have incentives to free-ride as their outside payoffs are zero (proposition 1); (b) that coalition G formed by the four countries is not internally stable, as country C is better-off outside; (c) that the only stable coalition is that which is formed by countries A, B & D because no-country (i.e., A, B & D) is better-off outside (internal stability), and no outside country (i.e., C) is better-off rejoining the coalition (external stability). Remember that for non-pivotal countries (iv) is $\frac{\sum_{i=1}^{I}\widehat{v}_i(X_G,x_i)}{I} = 0.97 \geq \theta_j(X_{G-j})$. In this example the only country with an outside payoff greater than the average initial payoff is country C, that is $\theta_c(X_{G-c}) = 2.64 > 0.97$.

We retain the stable coalition $G^* = \{A,B,D\}$. Its payoffs and transfer schemes are those of the second set in table 2. We analyze misrepresentation of mitigation costs and the willingness to pay parameters for countries belonging to the stable coalition when they announce a $\widetilde{c}_j(x_j) > c_j(x_j)$ or a $\widetilde{\theta}_j(X_{G^*}) < \theta_j(X_{G^*})$. We conclude that they always have incentives to deviate from the truth when the other countries state the truth. Finally, the best outcome of the game under the *horizontal equity-based* transfer is a Nash equilibrium characterized by this: countries A, B & D embark in a NAMAs coalition (i.e., they sign the NAMAs contract), and every country is better-off if country C remains as a free-rider.

Table 2: *Horizontal equity-based* transfer applied to illustrative example.[a]

Parameter	Country A	Country B	Country C	Country D	Total
Full cooperation					
$t_i(X_G, x_i)$	34.58	3.14	-27.97	-9.75	0.00
$v_{i\in G}(X_G, x_i, t_i)$	0.97	0.97	0.97	0.97	3.89
Country C free-rides, $X_{G-c} = 12.00$					
$t_i(X_{G-c}, x_i)$	18.11	-8.36	-	-9.75	0.00
$v_{i\in G}(X_{G-c}, x_i, t_i)$	0.71	0.71	(2.65)[b]	0.71	2.13
Country D free-rides, $X_{G-d} = 18.44$					
$t_i(X_{G-d}, x_i)$	30.61	-0.28	-30.34	-	0.00
$v_{i\in G}(X_{G-d}, x_i, t_i)$	3.07	3.07	3.07	(0.52)[b]	9.22
Country D leaves the coalition G^*, $X_{G^*} = 10.44$[c]					
$\theta_i(X_{G^*}, x_i)$	17.78	12.50	-	0.28[c]	30.27
$t_i(X_{G^*}, x_i)$	14.55	-11.61	-	0.00	0.00
$v_{i\in G}(X_{G^*}, x_i, t_i)$	3.22	3.22	-	(0.28)[b]	6.44
Country A announces $\widetilde{\theta}_A(X_{G^*}) = 18.00$					
$t_i(X_{G-c}, x_i)$	(17.56)[d]	-8.09	-	-9.47	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_A\right]$	1.26	0.44	-	0.44	2.13
Country B announces $\widetilde{\theta}_B(X_{G^*}) = 13.00$					
$t_i(X_{G-c}, x_i)$	18.19	(-8.52)[f]	-	-9.67	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_B\right]$	0.63	0.87	-	0.63	2.13
Country B announces $\widetilde{c}_B(x_B) = 22.00$					
$t_i(X_{G-c}, x_i)$	18.48	-9.10	-	-9.38	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_B\right]$	0.34	1.45	-	0.34	2.13
Country D announces $\widetilde{\theta}_D(X_{G^*}) = 0.10$					
$t_i(X_{G-c}, x_i)$	18.18	-8.30	-	(-9.88)[d]	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_D\right]$	0.65	0.65	-	0.84	2.13
Country D announces $\widetilde{c}_D(x_D) = 10.00$					
$t_i(X_{G-c}, x_i)$	18.34	-8.14	-	-10.19	0.00
$v_{i\in G}\left[(X_{G-c}, x_i, t_i), \widetilde{t}_D\right]$	0.49	0.49	-	1.15	2.13

Notes:

[a] All figures are given in the same numeration (u).

[b] These values are not included in the total column. Furthermore, they correspond to $\theta_i(X_{G-i})$.

[c] We assign $\theta_i(10.44) = (1/18)\text{GDP}_i$.

[d] This value corresponds to $\widetilde{t}_i(X_{G^*}, x_i)$.

4.2 The transfer à la Weikard

In this section, we apply the transfer *à la Weikard* to the feasible set $\{\vec{X}, \vec{T}\}$ presented in table 1. Table 3 shows the results for full cooperation, free-riding and misrepresentation which we analyze in section 3.2. Proposition 3 holds since this transfer always allows the implementation of a budget-balanced NAMAs portfolio (ii) and countries receive zero or positive payoffs (i). Note that the surplus payoff is the same as under the *horizontal equity-based* transfer. However, transfers *à la Weikard* redistribute initial payoffs of countries to those countries which have the higher outside payoffs, the non-pivotal countries C & D. All transfers paid by pivotal countries are allocated to non-pivotal countries. As a result, pivotal countries receive zero as their final payoff. We discover that the NAMAs coalition G formed by all countries is stable (i.e., the grand coalition). No country has an incentive to leave.[21] This result shows that this transfer scheme is better than the *horizontal equity-based* transfer scheme. However, as for the *horizontal equity-based* transfer scheme, every country is better-off misrepresenting its type, either underestimating its environmental gain or over-reporting its mitigation costs.

5 Policy implications and concluding remarks

In this paper, we envisage the implementation of a NAMAs portfolio by means of two transfer schemes: a *horizontal equity-based* and an "optimal" transfer which we call *à la Weikard*. We model NAMAs as a non-cooperative, one shot game. We then find the following results.

First, these transfer schemes may allow the implementation of a NAMAs coalition which is balanced and individually rational. That is, if NAMAs occur, then these transfer schemes ensure that no country will receive a negative final payoff and that the sum of transfers among countries is zero. The latter feature guarantees that there is no need for external source of funds to finance NAMAs. Therefore, these transfers make of NAMAs a "self-financing" climate policy instrument.

Secondly, concerning free-rider incentives, we have two main findings. On the one hand, NAMAs is "self-enforcing" for countries which are pivotal for the NAMAs portfolio regardless of the transfer scheme employed. This result entails one main policy implication: if the definition of a pivotal country is taken into account in the design of NAMAs, then pivotal countries are the most interested in the realization of NAMAs, even if they pay the highest transfers. Thus, "no-action" is not a credible threat for pivotal countries, as would usually be thought. Nevertheless, we consider that more research has to be undertaken to elucidate the role of pivotal countries in global climate policies. On the other hand, the transfer *à la Weikard* allows the implementation of a self-enforcing NAMAs coalition, also for all non-pivotal countries if the eventual surplus payoff covers the total outside payoff options of these countries. Nevertheless, in this regard, the *horizontal equity-based* transfer does not avoid free-riding for non-pivotal countries with outside payoffs larger than the average initial payoffs. Obtaining a self-enforcing NAMAs coalition facilitates international MRV both for funding and GHG reductions.

[21] See $\theta_j(\cdot)$ values when free-riding in table 2.

Table 3: Transfer *à la Weikard* applied to illustrative example.[a]

Parameter	Country A	Country B	Country C	Country D	Total
Full cooperation					
$t_i\ (X_G, x_i)$	35.56	4.11	-30.24	-9.42	0.00
$v_i(X_G, x_i, t_i)$	0.00	0.00	3.24	0.64	3.89
Country A announces $\widetilde{\theta}_A(20) = 35.00$					
$t_i(X_G, x_i)$	35.00	4.11	-29.78	-9.33	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_A\right]$	0.56	0.00	2.78	0.55	3.89
Country B announces $\widetilde{\theta}_B(20) = 24.00$					
$t_i(X_G, x_i)$	35.56	3.11	-29.41	-9.26	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_B\right]$	0.00	1.00	2.41	0.48	3.89
Country B announces $\widetilde{c}_B(x_B) = 22.00$					
$t_i(X_G, x_i)$	35.56	3.00	-29.32	-9.24	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_B\right]$	0.00	1.12	2.32	0.46	3.89
Country C announces $\widetilde{\theta}_C(20) = 4.50$					
$t_i(X_G, x_i)$	35.56	4.11	-30.33	-9.34	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_C\right]$	0.00	0.00	3.33	0.56	3.89
Country C announces $\widetilde{c}_C(x_c) = 33.00$					
$t_i(X_G, x_i)$	35.56	4.11	-30.41	-9.26	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_C\right]$	0.00	0.00	3.41	0.48	3.89
Country D announces $\widetilde{\theta}_D(20) = 0.45$					
$t_i(X_G, x_i)$	35.56	4.11	-30.16	-9.51	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_D\right]$	0.00	0.00	3.16	0.73	3.89
Country D announces $\widetilde{c}_D(x_D) = 10.00$					
$t_i(X_G, x_i)$	35.56	4.11	-29.69	-9.98	0.00
$v_i\left[(X_G, x_i, t_i), \widetilde{t}_D\right]$	0.00	0.00	2.69	1.20	3.89

Notes:

[a] All figures are given in the same numeration (u).

Thirdly, these transfer schemes do not avoid asymmetric informational problems when countries misrepresent either their mitigation costs or environmental gains from the NAMAs portfolio. This result is in line with the **Myerson-Sattertwhaite** impossibility theorem: there is not, in general, a mechanism (i.e., transfer) that it is efficient, balanced, individually rational and incentive compatible (i.e., that avoids asymmetric information). Therefore, policy makers, depending on their priorities, have to choose between mechanisms for avoiding asymmetric information and transfers that are efficient, balanced and individually rational or monitoring to prevent misrepresentation.

Fourthly, the *horizontal equity-based* transfer scheme guarantees that every country (either pivotal or non-pivotal) receives the same final payoff. The transfer *à la Weikard* allocates transfers in a way which means that pivotal countries receive zero as a final payoff and, thus, the surplus payoff is shared only among non-pivotal countries. Here, policy makers have a trade-off if they assess the implementation of NAMAs under one of these transfer schemes, namely, simplicity and political acceptability against institutional enforceability. If policy makers look rather for simplicity and political acceptability, then they may choose the *horizontal equity-based* transfer scheme because it should be seen as more pragmatic due to the fact that each country receives the same final payoff of reducing GHG emissions. However, if the institutional enforceability of NAMAs is low then some non-pivotal countries would free-ride. On the contrary, if policy makers are more interested in the fact that NAMAs works as a "self-enforcing" agreement which reduces the transaction cost of building strong institutions, they may favor the employment of the transfer *à la Weikard*. Nevertheless, estimating the outside payoffs of countries when free-riding would not be an easy task. In addition, the political acceptability of this transfer for pivotal countries may be a problem, as these countries are the largest transfer contributors and they receive zero as their final payoff.

Finally, we show our main theoretical findings by means of an illustrative example. We find that, under some specific assumptions, the DCs undertaking a *partially supported NAMAs* is the only one which has incentives to free-ride when the *horizontal equity-based* transfer scheme is employed. This kind of country is characterized by having medium GHG emission objectives and marginal abatement costs as well as middle-to-low environmental gain from avoiding GHG emissions. This fact may suggest that if the *horizontal equity-based* transfer scheme is employed to implement NAMAs, then NAMAs may be focused, in a first instance, on DCs with the highest and lowest initial valuation (i.e., initial payoff) on the NAMAs portfolio.

Acknowledgments

This research was carried out with the financial support of the project "Modelling Sectoral Climate Change Policies: Mitigation, Adaptation, and Acceptance" (MIADAC) of Swiss NCCR-Climate program.

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